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roughly approximate, having been obtained just as daylight was coming on.

October 17.	October 18.	October 25.	November 2.
Yellow band	Yellow band	Yellow band	554
Green band	Green band	Green band	515
488	488	4864	4862
Blue band	Blue band	Blue band	470
45	455	455	4557

November 3, 1893.

PRELIMINARY NOTE ON A MECHANICAL THEORY OF COMETS.

By J. M. Schaeberle.

In my paper on "A Mechanical Theory of the Corona," written three years ago, the concluding paragraph begins as follows:

"The hypothesis, favored by some astronomers, that the matter now revolving about the Sun in cometary orbits was once ejected from the Sun is, according to the Mechanical Theory, rendered extremely probable, and it would not be difficult to bring forward many strong arguments to support this view, and to account for many apparent changes of form in cometary matter."

Lately, various data (especially those given by my large coronal photographs of the last eclipse) have become available, the character of which is such that no apology is needed for presenting my views on the nature of comets at this time, especially as this new theory of comets is a strictly logical consequence of the mechanical theory of the corona.

Direct observations of the Sun's immediate surroundings demonstrate the presence of masses of matter ejected from the Sun with very great velocity. That this matter is not of a uniform density seems to be plainly proved by the evidence of the eclipse photographs. The prominences, for instance, rise to certain limiting heights, corresponding to certain definite initial velocities of motion. The coronal streams, on the other hand, rise to indefinite heights, and must therefore have, in general, much greater initial velocities.

Any given eruption doubtless gives rise to both prominences and streams. As the ejective force may be assumed common to both, the mass of a given volume of a coronal stream must be less than that of a prominence, and this evidence is given by all eclipse photographs showing both forms.

Now let v denote the velocity of a portion of a prominence whose mass to a given volume is m, and let v' denote the velocity of a portion of a coronal stream whose mass for the same volume is m', then for the same ejective force F we shall have, if atmospheric resistances are zero,

$$F = m\,v^2 = m'\,v'^2$$

or,

$$v' = v\sqrt{\frac{m}{m'}}$$

The individual particles going to make up the mass m, for example, will not necessarily have equal masses; but, on account of their proximity to each other, all are constrained to have a common velocity v. Similarly all the particles in the mass m' are forced to move with the common velocity v'.

If now we assume the mean density of a coronal stream to be even as great as one-seventh of that of an accompanying prominence, the same explosive force which during the last eclipse sent prominence matter to a height of 80,000 miles, will send coronal matter forming the streams to an infinite distance.

Each eruption, then, is sending out minute particles of matter with great velocity, and the solid angle of the conical surface inclosing them all may evidently be quite large. Aside from gravitational influences these particles suffer no resistance to motion in space, except where they come into contact with other particles of matter moving in vacuo.

If each particle moves along a normal to the Sun's surface, the density at any given point of a stream will vary inversely as the square of the distance from the Sun's center, and inversely as the velocity; but, as the velocity varies inversely as the square root of the distance, the density must vary inversely as the cube of the square root of the distance from the Sun's center.

In the following table the velocities and corresponding densities of a stream have been computed for various distances from the Sun, assuming an initial parabolic velocity. The density near the Sun's surface is placed equal to unity. The unit of distance is the Earth's mean distance from the Sun.

Distance.	Velocity in miles per sec.	Density.	Distance.	Velocity in miles per sec.	Density.
0.005	370	0.936	0.10	82.7	0.0100
.006	338	.712	.20	58.5	.0037
.007	313	.565	.30	47.8	.0020
.008	292	.462	.40	41.4	.0013
.009	276	.387	.50	37.0	.0009
			.60	33.8	.0007
.01	262	.331	.70	31.3	.0006
.02	185	.117	.80	29.2	.0005
.03	151	.064	.90	27.6	.0004
.04	131	.041			
.05	117	.030	1.0	26.2	.00030
.06	107	.023	2.0	18.5	.00012
.07	99	.018	3.0	15.1	.00006
.08	92	.015	4.0	13.1	.00004
.09	87	.012	5.0	11.7	.00003
0.10	83	0.010	6.0	10.7	0.00002

The above densities refer to streams having a parabolic velocity for which the density becomes zero when the distance is infinite. I find, however, that for a certain limiting elliptical velocity (limiting only because of the Sun's rotation) the density at first decreases with the distance, then a gradual increase takes place until the densest portion of the whole stream is at the point where the velocity is least. Additional evidence that the coronal matter visible during the last eclipse was in rapid motion, is to be found in the observed fact that the curved returning coronal streams shown on my large photographs are apparently most dense in the higher regions. The same is true of the distribution of the prominence matter.

With the foregoing principles as a basis, I now come to a new theory of comets which has for its foundation only the simple action of purely mechanical forces, and entirely independent of those occult forces—electricity and magnetism.

As I shall treat the subject from a purely theoretical standpoint, all the statements and deductions here given refer to a theoretical comet produced by the theoretical causes named.

1. A comet (theoretical) is a large meteor whose composition is of such a nature that certain (or all) of its constituents are evaporated at comparatively low temperatures. The atmosphere

thus formed will, on account of the small mass, always be most dense on the side where the evaporation is most rapid. When the evaporation ceases, this atmosphere will tend to arrange itself symmetrically with reference to the nucleus so long as no other material bodies come into contact with it. Tidal effects will always have a tendency to cause greater or less dissymmetry of form.

2. An increase of temperature, brought about both by a diminishing distance from the Sun and by collisions with minute material particles in space, will be accompanied by a corresponding increase in the mass of the surrounding atmosphere, due both to a more rapid evaporation from the nucleus and to a temporary or permanent capture of the colliding particles.

3. The attraction which the nucleus exerts upon its atmosphere is so extremely small that each of the more distant particles of this atmosphere can be considered as describing an independent orbit, the mean of the separate orbits thus described practically coinciding with that of the nucleus. When the meteorite is very near the Sun the evaporation on the Sun side of the nucleus will be very rapid, which combined with tidal influences may result in the rupture of the nucleus.

4. The tail of a comet (theoretical) is produced both by the visible particles of matter originally forming the comet's atmosphere, and by the previously invisible particles of a coronal stream which, moving with great velocity, finally produce by repeated impact of the successive particles almost the same motions in the visible atmosphere of the comet as would be communicated by a continuously accelerating force directed away from the Sun. The actions on the particles of the stream result in a diminution of the velocity of the more advanced portions which now become visible through a consequent increase of density. A peculiarity of this mechanical accelerating force is that it becomes zero when the particle repeatedly struck by a succession of other particles finally attains the same finite velocity as the stream of striking bodies.

5. As all the particles of a given coronal stream have the same velocity, the momentum of the heavier sets of particles will be greater than the momentum of those having less mass. Let $m_1, m_2, m_3 \ldots . m_n$ denote the masses of different particles of the

stream which strike the comet's atmosphere; the total momentum at a given instant will be

$$v^2 \Sigma m = v^2 \Sigma m_1 + v^2 \Sigma m_2 + v^2 \Sigma m_n$$

A particle whose mass is m, will penetrate the atmosphere to a distance s, before being brought to a state of rest relatively to the nucleus. Similarly the particles whose masses are m_2, $m_3 \ldots . m_n$ will penetrate the atmosphere to the respective distances $s_2, s_3 . \ldots . s_n$. The resulting strata of increased density of the comet's atmosphere will evidently be nearly concentric, the distances between any two strata f and t being $(s_f\text{-}s_t)$.

These strata of increased density will in projection be made manifest in the form of luminous and nearly concentric arcs whose greatest brilliancy will, in general, be near the most advanced part of each stratum, and gradually diminish in brightness as they curve away to form the comet's tail.

6. The coronal matter, owing to its retardation, grows so dense that it also becomes visible, and with the comet's atmosphere, is finally driven into the tail by the repeated bombardment of unretarded following portions of the stream.

It is evident that the resulting velocity of different parts of the comet's tail will depend both upon the mass of each individual striking particle and upon the mass of the particle struck. In general, the coronal particles which have the greatest mass will after collision give the greatest velocity, which is gradually accelerated as above described until the speed again becomes so great that no sensible illumination results from the scattered particles. The nucleus and inner portions of the atmosphere, being the most dense, block the passage of the particles so that the axis of the tail will usually have less matter than the space at some distance from the axis.

To keep this note within proper bounds, further general considerations must be published in another form. A simple inspection of the figures given in the preceding table will at once show how greatly the factor depending upon the distance from the Sun influences the form of a comet in general.

The severest test of any given theory is its ability to account for abnormal deviations from a typical form. Some of the most remarkable will be briefly considered.

Many coronal streams issue from the Sun at considerable angles with the normals; in space, therefore, different streams will cross each other without sensibly interfering with each other's motions. The atmosphere of a comet, however, when placed at such a crossing, will evidently produce as many different tails to the nucleus as there are crossing streams; the angles between the tails being a function of the velocities of motion and the inclinations of the streams.

There are several cases on record of comets having a tail turned *toward* the sun in addition to the usual appendage. I have examined every case known to me, and find that invariably at the time this phenomenon was observed the comet was *receding* from the Sun with great velocity. *A coronal stream, having a less velocity than that of the receding comet, will under these circumstances cause just such a phenomenon the moment the comet enters the stream.* Evidently the main tail will in no way be sensibly affected, since the tenuity of the two coronal streams (one moving with greater velocity than the comet, and the other with less velocity) is so great that no sensible interdisturbance takes place.

Owing to the orbital motion of the comet, different tails will result when the velocities in the tail (as a whole) at a given distance from the nucleus are largely and abruptly different. The curvature will be greatest for the tail which has the least velocity. If a gradual variation in the velocity results, a gradually broadening tail (in general more curved in projection on one side than on the other) will result.

Rapid variations in the form and brightness of the comet will result from the lateral orbital motion of the comet with respect to the stream, often passing from one stream into another. A comet loses its tail if for a considerable time it passes from a stream of greater (or less) velocity, into space sensibly devoid of coronal matter, or into a stream having the same velocity and direction of motion.

When the velocity of the particles in the more distant portions of the tail is much less than that of the streams, the deviation of the axis of the tail from the produced radius vector of the nucleus will become so great that fresh and unretarded streams can plough their way through (across) these more distant parts of the tail, which may result in a visible phenomenon of a striated or columnar structure (as actually observed by BOND and others, in DONATI'S comet); the axis of each column being roughly parallel to the direction of these coronal streams.

Sudden and sharply abrupt changes in the direction of a comet's tail at great distances from the nucleus will be caused whenever the tail enters another coronal stream whose direction of motion is considerably inclined to the stream passing through the comet's nucleus.

A natural consequence of such motions of coronal matter is to deprive all bodies, of very small mass of any non-growing atmosphere they may have; and also to fix the limit of distance beyond which a body of great mass cannot retain its atmosphere. In this connection I would again call attention to the fact that the phenomenon of the "Gegenschein" can be quite satisfactorily explained on this hypothesis, and that the results following from the capture of coronal particles by our own atmosphere lead to a plausible explanation of the aurora. [See December, 1889, Eclipse Report, LICK Observatory.]

This paper, as indicated by the title, is but a preliminary note on a theory which will be more completely discussed in the forthcoming "Report on the Eclipse of April 16, 1893."—Reprinted from *The Astronomical Journal*, No. 306.

(FOURTEENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor W. R. BROOKS, of Geneva, New York, for his discovery of an unexpected comet on October 16, 1893.

The Committee on the Comet-Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHARLES BURCKHALTER.

December 16, 1893.